NASAfacts

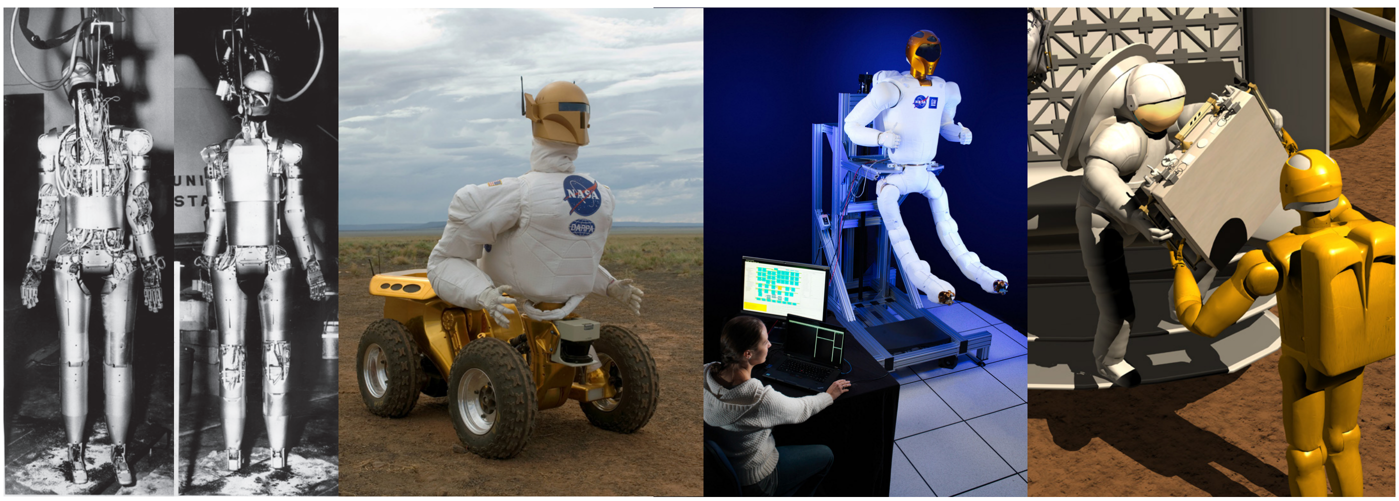
Robonaut 2

Robonaut 2 has been on board the International Space Station since launching aboard space shuttle Discovery on the STS-133 mission in February 2011. It is the first humanoid robot in space, and although its primary job for now is demonstrating to engineers how dexterous robots behave in space, the hope is that, through upgrades and advancements, it could one day venture outside the station to help spacewalkers make repairs or additions to the station or perform scientific work.

R2, as the robot is called, powered up for the first time in August of 2011. Since then, robotics engineers have tested R2 inside the Destiny laboratory, completing tasks ranging from velocity air measurements to handrail cleaning, simple but necessary tasks that require a great deal of crew time. R2 also has a taskboard on which to practice flipping switches and pushing buttons and has been controlled by station crew members on multiple occasions through the use of virtual reality gear. There are no plans to return R2 to Earth.

History
Work on the first Robonaut began in 1997. The idea was to build a humanoid robot that could assist astronauts on tasks in which another pair of hands would be helpful or to venture forth to perform jobs either too dangerous for crew members to risk or too mundane for them to spend time on. The result was R1, a human-like prototype of a robot that could perform maintenance tasks or be mounted on a set of wheels to explore distant destinations. Through 2006, R1 performed in numerous experiments in a variety of laboratory and field test environments, proving that the concept of a robotic assistant was valid. The same year, General Motors expressed an interest in hearing about the project. They had been developing their own dexterous robots, and after seeing what NASA had already accomplished, GM proposed teaming up. A Space Act Agreement was signed in 2007 to allow GM and NASA to pool resources and work together on the next-generation Robonaut.

In February 2010, R2 was unveiled – a faster, more dexterous, more technologically advanced humanoid robot than had ever been seen before. Its potential was quickly recognized, and space was made on space shuttle *Discovery's* final mission to provide it a ride to the space station. There it is making both history, as the first humanoid robot in space, and progress as engineers get their first look at how a humanoid robot actually performs in the absence of gravity.



Future
The International Space Station is only the first of R2's possible missions. The conditions aboard the space station provide an ideal proving ground for robots to work shoulder to shoulder with people in microgravity. Software upgrades and the arrival of the new leg system will allow R2 to move around and, after further upgrades and testing, eventually work outside in the vacuum of space. This will help NASA understand robotic capabilities for future deep space missions.

As R2 technology matures, similar robots could be sent deeper into space to test the system in more extreme thermal and radiation conditions. Someday, R2 could service communications, weather and reconnaissance satellites, which have direct benefits on Earth.

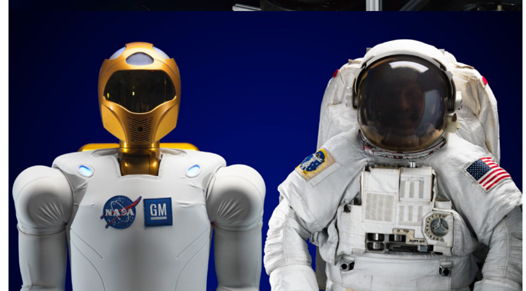
The next step for robotic capabilities such as R2 would be to explore near-Earth objects, including asteroids and comets, and eventually Mars and Mars' moons. The robot will serve as a scout, providing advanced maps and soil samples, and beginning work on the infrastructure that astronauts would need. The crew that follows would then be much more prepared for the exploration ahead.

This evolution of capabilities for both robotic and human exploration will make a Mars surface mission possible. This human-robotic partnership will allow Mars surface missions to be conducted safely by a smaller crew – without sacrificing mission plans and results.

There is a logical progression for the next generation of space exploration. Our first look at a new destination is through a telescope, then through the eyes of a robotic precursor such as R2, followed by arrival of human explorers. Humans and robots exploring the solar system together will provide greater results than either could achieve alone, enabling an exciting future of new discoveries.

Legs
To allow R2 to move around onboard the space station, robotic legs have been built and are ready for launch – though they won't work quite the way legs work here on the Earth. In space, astronauts use their legs to hold their bodies in place by anchoring at different built in points around the station. The new additions to R2 will provide sufficient length for it to move between modules while always keeping a secure attachment to the ISS. Rather than balancing or walking on its legs, R2 is equipped with end effectors (its feet) which can grasp handrails and other built in capture points already used by astronauts to move from worksite to worksite or stay in one place.

Upgrading for Space
R2 was designed as a prototype to be used here on Earth as a way to better understand what would be needed to eventually send a robot to space. However, when R2 was unveiled, the system was so impressive that mission managers decided to go ahead and send it to the space station – but not without a few upgrades. Outer skin materials were exchanged to meet the station's stringent flammability requirements; shielding was added to reduce electromagnetic interference; and processors were upgraded to increase the robot's radiation tolerance. The original fans were replaced with quieter ones to accommodate the station's restrictive noise environment, and the power system was rewired to run on the station's direct current system rather than the alternating current used on the ground.



Working on the Station
Initially, R2's primary role on the space station is experimental. The robot began its life in space stationed in the Destiny laboratory, where it will be put through tasks and operations similar to those that it has already performed on Earth, thus allowing engineers to work out issues with operating a dexterous humanoid robot in space. As R2 proves its mettle, the robot will graduate to station maintenance tasks. And with upgrades that would allow it to function in the vacuum of space, it could also perform repairs on the exterior of the station or simply help astronauts as they work outside.

Control/Operation
R2 operators have several choices for how to control the robot. Station crew members will be able to operate R2, as will controllers on the ground. However, one of the improvements over the previous Robonaut generation is that R2 doesn't need constant supervision. In anticipation of a future destination in which distance and time delays would make continuous management problematic, R2 was designed to be set to tasks and then carry them through autonomously with periodic status checks.

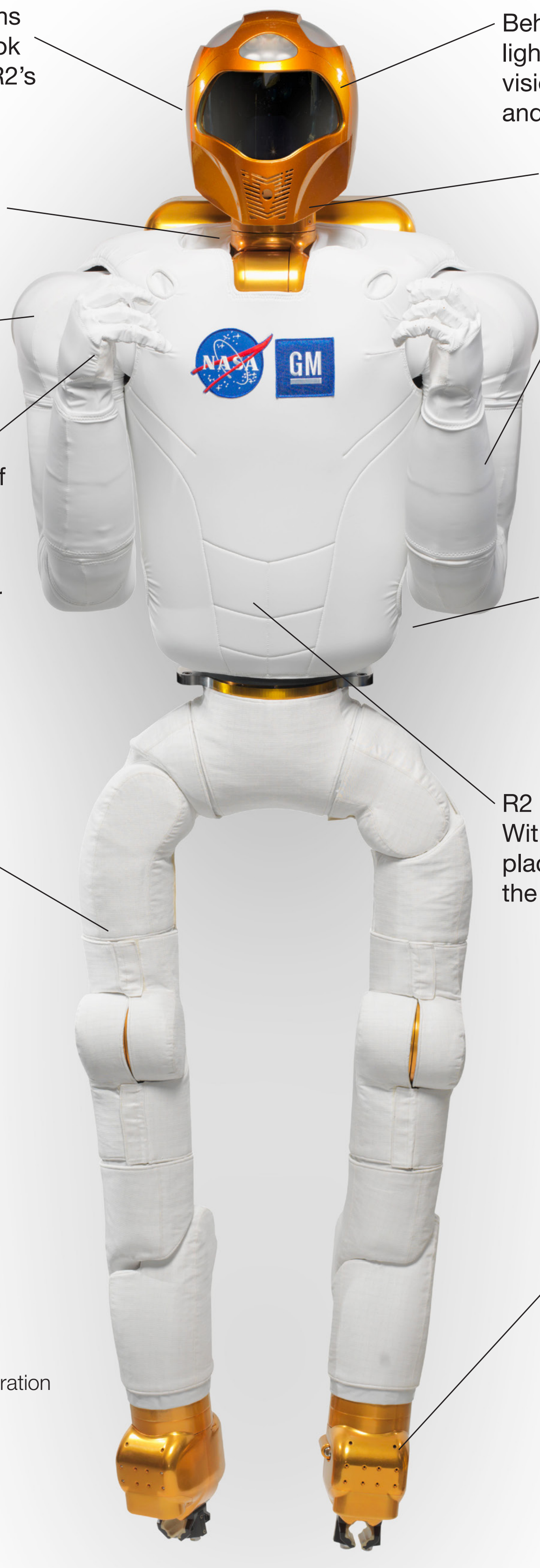
Centaur 2
Although humans use legs to get around in gravity, wheels will likely be a more efficient mode of transportation for R2 on planetary or lunar surfaces. For that purpose, a four-wheeled base for Robonaut is being tested. When riding atop the base, R2 becomes Centaur 2, named for the mythical half-man, half-horse creature. The Centaur base builds on the lessons learned in the development of Chariot, the chassis on which the Space Exploration Vehicle sits in its wheeled form. Like Chariot, the Centaur base can lower or raise itself to and from the ground and turn its wheels, individually or as a group, in any direction, allowing it to turn in place and drive in any combination of forward and sideways. With these features, Centaur 2 could remotely scout areas for potential crew visits or assist astronauts in spacewalks.

Specifications

Materials: Primarily aluminum with steel, and non-metallics.
Weight with legs: 490 pounds
Height: 8ft (with legs fully stretched)
Average height while in motion: Approx 5' 9"

Shoulder width: 2 feet, 7 inches
Sensors: 500+, total
Processors: 3 Core-I7s, 36 Power PCs, 16 ARMs
Degrees of freedom: 58, total with legs
Limb Speed: Up to 7 feet per sec

What Robonauts Are Made Of



A robot meant to work with humans and use human tools begins to look human-like by default. However, R2's head houses not its brain, but its vision equipment.

R2 has 3 degrees of freedom in its neck, allowing it to look left, right, up, or down.

Each arm is approx. 2 feet, 8 inches long, giving the R2 a total wingspan of 8 feet.

Robonaut 2's hands have 12 degrees of freedom – 4 degrees of freedom in the thumb, 3 degrees of freedom each in the index and middle fingers, and 1 each in the ring and pinky fingers. Each finger has a grasping force of 5 pounds.

R2 has new legs with 7 degrees of freedom that provide sufficient length to climb between modules. The double knees are not human like, but they provide flexibility to position the body as needed to perform tasks across ISS.

Behind R2's visor are four visible light cameras – two to provide stereo vision for the robot and its operators, and two auxiliary cameras.

A fifth infrared camera is housed in the mouth area for depth perception.

Each arm boasts 7 degrees of freedom and the strength to hold 20 pounds in any pose in Earth's gravity.

Here on Earth and at the space station, R2's backpack holds its power conversion system, allowing it basically to be plugged in. On another planetary surface – or on the moon or an asteroid – the backpack would hold the robot's batteries.

R2 thinks with its stomach – literally. With its head full of cameras, the only place with enough room for a brain is the robot's torso.

The end effectors (or feet) have grippers that can grasp ISS handrails and also engage seat track ensuring a stable attachment to ISS at all times.

National Aeronautics and Space Administration

Lyndon B. Johnson Space Center
Houston, Texas 77058

www.nasa.gov

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